
Ethnomathematics: A Study of Plane Geometry Concepts at the Walahar Dam

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Abstract

This study aims to explore ethnomathematical aspects in the Walahar Dam, particularly in identifying plane geometry concepts embedded in its architectural structures. This research employed a descriptive qualitative method. Data were collected through field observations, interviews with dam managers, and documentation. The results show that various plane geometry concepts are found in the Walahar Dam, including triangles, rectangles, trapezoids, circles, semicircles, tessellations, and composite shapes. These geometric forms are not only functional in structural design but also reflect cultural and aesthetic values influenced by Dutch colonial and Chinese architecture. The findings indicate that the Walahar Dam has significant potential as a contextual learning resource in mathematics, especially in teaching plane geometry concepts based on local culture. This study contributes to enriching ethnomathematics literature and supports the integration of cultural heritage into mathematics learning.

Keywords: ethnomathematics, Walahar Dam, plane geometry, cultural heritage, architecture

1. Introduction

Mathematics is a fundamental discipline that plays an essential role in human life, both in daily activities and in the development of science and technology. As a foundational science, mathematics contributes to the development of critical, systematic, and logical thinking skills, which are indispensable for problem-solving processes (Rahmaini & Chandra, 2024). Mastery of mathematics is also considered an important provision for younger generations in facing global challenges; therefore, the quality of mathematics education is often used as an indicator of a

nation's educational success (Intan et al., 2022). Despite its importance, mathematics is widely recognized as an abstract discipline. This abstract nature aligns with philosophical perspectives that position mathematics as a deductive science with a high level of generalization, where truth is obtained through logical reasoning rather than empirical experimentation (Isnaintri et al., 2023). Such abstraction often causes students to experience difficulties in connecting mathematical concepts with real-life contexts, particularly in plane geometry topics, which are frequently perceived as difficult and less meaningful (Sinaga et al., 2021).

Previous studies have shown that students' mathematical connection abilities remain relatively low. Tresnawati and Aini (2022) reported that junior high school students demonstrated limited ability to connect concepts of triangles and quadrilaterals with their applications in everyday life. This condition indicates the need for learning approaches that can bridge the gap between abstract mathematical concepts and students lived experiences. Consequently, efforts are required to explore mathematical concepts that are inherently close to human life and the surrounding environment (Yudianto et al., 2021). Mathematics is often perceived as merely a collection of numbers and formulas; however, its development cannot be separated from human historical and cultural experiences (Frisnoiry et al., 2024). Practical human needs such as land measurement, architectural design, and agricultural planning have given rise to fundamental mathematical concepts that continue to evolve. Historically, mathematics has developed through continuous human interaction with the environment and has been significantly influenced by cultural practices (Talib et al., 2025). In contemporary education, this relationship is reflected through the ethnomathematics approach.

According to D'Ambrosio (1985), ethnomathematics the mathematics which is practiced among identifiable cultural groups, such as national-tribal societies, labor groups, children of a certain age bracket, professional classes, and so on. This perspective emphasizes that each cultural group possesses unique ways of understanding and applying mathematical concepts based on their activities and lived experiences. Thus, mathematics is viewed not merely as abstract knowledge but also as a cultural product embedded in social life. Through ethnomathematics, mathematics learning can be explored more deeply by utilizing cultural contexts (Nova & Putra, 2022). Ethnomathematics is understood as an approach that situates culture as a meaningful context for learning mathematical concepts, emphasizing that cultural diversity leads to diverse forms of mathematical knowledge (Izah & Malasari, 2021; Marlissa et al., 2024). This approach enables students to comprehend mathematical concepts more concretely because learning is connected to familiar daily practices (Wildan et al., 2024). As a result, mathematics is no longer perceived as distant or abstract, but as knowledge that grows and develops within society.

Ethnomathematics research continues to expand by utilizing local cultural wealth from various regions in Indonesia, integrating it into mathematics learning contexts (Maharani, 2024). Local culture can be manifested in cultural products such as architectural artifacts, which can be explored through mathematical concepts (Lisnani et al., 2022). Studies on ethnomathematics in historical or traditional buildings commonly focus on geometric aspects, including overall forms and architectural elements such as columns, doors, windows, and other structural components (Silviana et al., 2024). However, most of these studies remain concentrated on specific regions or structures, while ethnomathematical studies on historical buildings in Karawang Regency, particularly the Walahar Dam, are still limited.

The Walahar Dam is a historical structure built during the Dutch colonial period between 1920 and 1925 as part of the irrigation system regulating the flow of the Citarum River. Architecturally, the dam represents a fusion of Dutch engineering and Chinese aesthetic influences, visible in its roof structures and ornamental details. This cultural integration results in a structure that is not only functional but also aesthetically and mathematically rich. The dam contains various geometric forms that are highly relevant for contextual mathematics learning; however, these potentials have not been widely documented in ethnomathematics studies.

Previous research by Agustin and Soebagyo (2024) identified several plane geometry forms at the Walahar Dam, such as isosceles triangles, rectangles, circles, and composite shapes, and discussed their implications for mathematics learning. Nevertheless, the study focused on a limited range of geometric forms and did not comprehensively explore other geometric concepts present in the structure. Therefore, this study aims to provide a more systematic and comprehensive ethnomathematical exploration of plane geometry concepts embedded in the Walahar Dam. By doing so, this research seeks to enrich ethnomathematics literature while contributing to the preservation of local cultural heritage through mathematics education.

However, previous studies on ethnomathematics in historical buildings tend to focus on limited geometric aspects and have not comprehensively explored the variety of plane geometry concepts within a single cultural object. In particular, studies on the Walahar Dam remain limited and have not systematically analyzed its architectural elements from an ethnomathematical perspective. Therefore, this study seeks to fill this gap by providing a more comprehensive exploration of plane geometry concepts embedded in the Walahar Dam and their potential as contextual learning resources.

2. Methods

This study employed a descriptive qualitative research design. This approach was selected because it is appropriate for identifying, analyzing, and describing phenomena that contain mathematical values within a cultural context (Sugiyono, 2023). The focus of the study was the identification of plane geometry concepts embedded in the architectural structures of the Walahar Dam. The research was conducted at the Walahar Dam, located in Karawang Regency, West Java, Indonesia. The object of the study was the physical structure of the dam that represents elements of plane geometry, while the subjects were the dam managers who served as key informants. The informants in this study consisted of two dam management staff who were selected purposively based on their knowledge and involvement in the maintenance and operation of the Walahar Dam.

In qualitative research, the researcher acts as the main research instrument and is directly involved in the processes of data collection and analysis. To support this role, several research instruments were used, including observation guidelines, interview protocols, and documentation tools. The observation guidelines focused on identifying geometric shapes in the architectural structures, while the interview protocols were designed to obtain information regarding the historical background, function, and design considerations of the dam. Data were collected through direct field observations to examine the architectural structures of the dam, semi-structured interviews with the dam management, and documentation in the form of photographs and relevant literature. The collected data were analyzed using the interactive analysis model proposed by Miles and Huberman, which consists of three stages: data reduction, data display, and conclusion drawing (Sugiyono, 2023). Data validity was ensured through source triangulation and technique triangulation by comparing findings from observations, interviews, and documentation. This procedure was applied to enhance the credibility and trustworthiness of the research findings.

The data analysis was conducted through several stages. First, data reduction was carried out by selecting relevant information related to geometric forms identified in the dam structure. Second, data were categorized based on types of plane geometry concepts such as triangles, rectangles, and circles. Third, the data were interpreted by linking the identified geometric forms with ethnomathematical perspectives and their potential application in mathematics learning. Finally, conclusions were drawn based on the patterns and relationships found during the analysis process.

3. Result and Discussion

This study aims to identify cultural and structural elements of the Walahar Dam that contain plane geometry concepts. Based on information obtained from interviews with the officers responsible for maintaining this historical structure, the construction of the Walahar Dam was driven by the urgent need for water resources in Karawang Regency in the past. In particular, northern Karawang experienced water shortages that caused instability in agricultural production. Therefore, the primary function of the Walahar Dam was to irrigate rice fields surrounding the Karawang region.

Information from the inscription located in the bridge corridor indicates that the Walahar Dam began operating on November 30, 1925, to irrigate approximately 87,396 hectares of agricultural land. The existence of the Walahar Dam cannot be separated from the Citarum River, which serves as its main water source. The Citarum River is widely recognized as a vital lifeline for communities in West Java, functioning as a source of clean water for residents of Bandung, Cimahi, Cianjur, Purwakarta, Bekasi, and Karawang, irrigating agricultural land, and contributing to industrial waste management (Raharja & Chan, 2021).

The Walahar Dam consists of three main sections. The first section is the lower part, which includes six water control gates. The second section is a bridge that connects the Klari and Anggadita areas. The third section is the engine room, which functions to regulate the dam's operating system. Based on field observations conducted during the study, several plane geometry concepts were identified in the structural components of the Walahar Dam, as described below.

Figure 1.

Entrance Roof of Walahar Dam



Based on Figure 1, it can be observed that the entrance of the Walahar Dam has a triangular-shaped roof. A triangle is a plane figure consisting of three straight sides that meet at their endpoints

and form angles (Silviana et al., 2024). The triangular shape observed is an isosceles triangle, characterized by a roof peak located precisely at the center as the highest point, with two sloping sides descending symmetrically to the left and right. The base of the triangle is formed by a horizontal line at the lower part of the roof, directly above the uppermost wall. This finding indicates that geometric concepts are not only used for structural purposes but also reflect implicit mathematical reasoning embedded in architectural practices.

An isosceles triangle has several characteristics, including two sides of equal length (slanted sides), two congruent angles, and one axis of symmetry (Safitri et al., 2021). In addition, formulas can be used to calculate the area and perimeter of an isosceles triangle, as presented below.

$$\text{Area of a triangle} = \frac{1}{2} \times a \times t$$

$$\text{Perimeter of a triangle} = a + b + c$$

The selection of a triangular roof form also represents an adaptation of colonial architecture to tropical climates, as steep roofs allow rainwater to flow more quickly, thereby reducing structural load and the risk of damage. Colonial buildings in Indonesia are known to adopt sharply angled roof designs as a strategy to cope with high rainfall while maintaining thermal comfort in interior spaces (Bu'ulolo et al., 2020). Beyond its structural function, the triangular roof form also reflects a philosophy of balance and stability in colonial architecture that blends with local cultural values (Azabit & Zulfikar, 2025).

Figure 2.

Ornamental Tessellation on the Upper Wall of the Walahar Dam



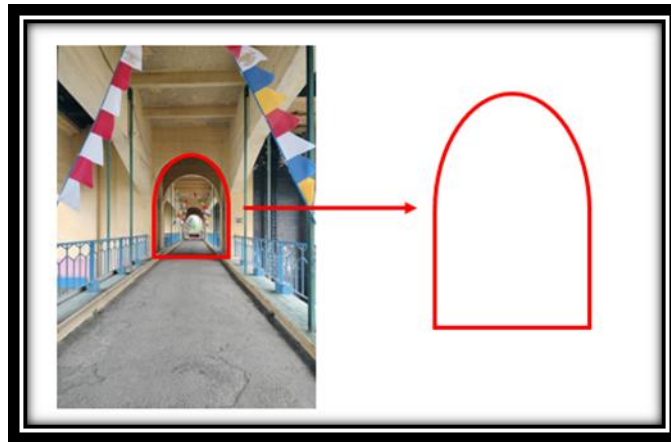
Based on Figure 2, a distinctive Chinese-style ornament can be observed on the upper part of the Walahar Dam building. The ornament appears as an elongated yellow decorative element with a repetitive pattern. The pattern resembles small squares or rectangles arranged in parallel, with variations of internal lines that create a symmetrical appearance. This ornament can be understood as an application of the tessellation concept. Tessellation, also known as tiling, refers to a specific pattern formed by geometric shapes arranged to completely cover a plane without

leaving gaps or overlapping (Wardani & Budiarto, 2022). Therefore, the ornamental element found on the Walahar Dam building can serve as a concrete example of the application of tessellation concepts in plane geometry.

These findings are in line with the concept of ethnomathematics proposed by D'Ambrosio (1985), which emphasizes that mathematical ideas are embedded in cultural practices and artifacts. The repetitive pattern found in the ornament demonstrates how mathematical ideas such as symmetry and tessellation are integrated into cultural artistic expressions. The presence of geometric forms in the Walahar Dam demonstrates that mathematics is not only abstract but also constructed through real-life human activities.

Figure 3.

Arched Structures in the Bridge Corridor of the Walahar Dam



Based on Figure 3, in the bridge section used as a crossing route connecting Klari District and Ciampel District, there is a series of buildings containing several interior spaces. The corridor of this historical structure at the Walahar Dam displays a combination of plane figures in the form of a rectangle with a semicircle at the upper part. A rectangle is a special type of parallelogram that has two pairs of parallel sides and four right angles (90°) (Rahayu et al., 2025). Meanwhile, a semicircle is a plane figure formed by dividing a complete circle by a line passing through its center and ending at the circumference (Silviana et al., 2024).

Interestingly, along the corridor there are twelve identical arched forms, each combining a rectangular base with a semicircular top. The repetitive arrangement of these two plane figures makes the corridor appear symmetrical and aesthetically pleasing. This composite form of a rectangle and a semicircle represent an adaptation of Dutch colonial architecture to tropical climates, as it not only supports air circulation and natural lighting but also enhances aesthetic

value (Talib et al., 2025). The presence of large openings and curved elements in several parts of the building illustrates how colonial architecture employed geometric forms to support cross-ventilation and structural strength in dam structures (Bu'ulolo et al., 2020).

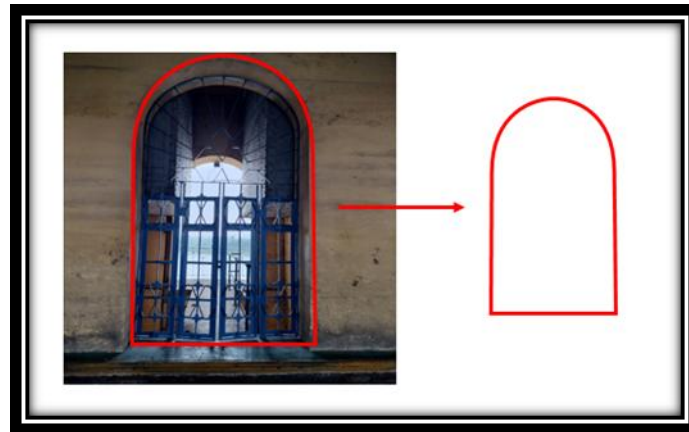
From a mathematical perspective, the area of the arched structure in the Walahar Dam corridor can be calculated by summing the area of the rectangle and the area of the semicircle. Meanwhile, the perimeter of this composite figure is obtained by adding three sides of the rectangle and half of the circumference of a circle. Thus, the area and perimeter can be expressed as follows.

$$Area = (p \times l) + \frac{1}{2} \pi r^2$$

$$Perimeter = 2(p + l) + \frac{1}{2} \times 2\pi r$$

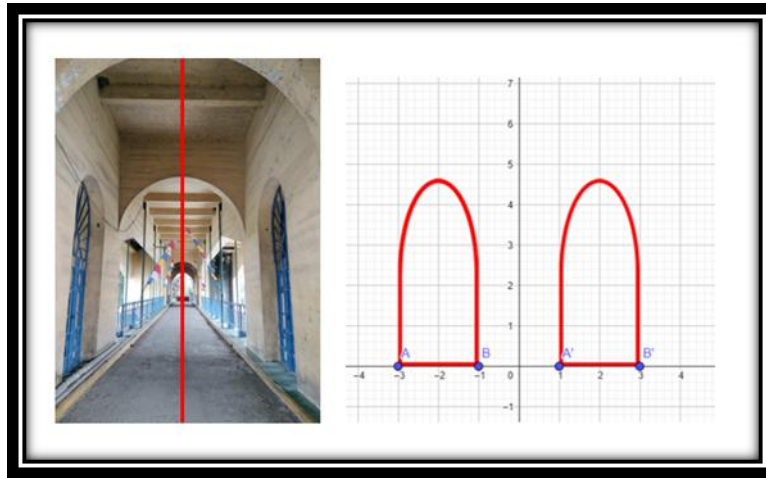
Figure 4.

Window Structures with Semicircular Arches



Based on Figure 4, the concept of composite plane figures in the form of rectangles and semicircles is also found in the windows of the Walahar Dam. Each main window opening is framed by a rectangular base structure with pairs of parallel sides and right angles, while the upper part is curved to form a semicircle. The exploration of the window structures at the Walahar Dam revealed a total of 18 arched grille windows arranged symmetrically. Each window is positioned facing its counterpart on the upstream and downstream sides, forming congruent pairs that are identical in both size and shape. This arrangement demonstrates the application of a mathematical concept known as reflection symmetry, in which a window on one side serves as the mirror image of a window on the opposite side.

Figure 5.
Symmetrical Arched Doors of the Walahar Dam



Based on Figure 5, a series of arched doors can be observed facing each other on the left and right sides of the building. These doors can be analyzed using the concept of geometric transformation, particularly reflection. Reflection is a type of geometric transformation, also known as mirroring, in which an object is mapped onto its image while preserving its size and distance (Faturrahman & Soro, 2021).

If an imaginary line is drawn along the center of the pathway as the axis of symmetry (y-axis), the door on the left side becomes the reflected image of the door on the right side, and vice versa. The curved shape at the top of each door further emphasizes the presence of mirror symmetry, as the two doors appear identical in form but are positioned on opposite sides. This reflects those geometric transformations, such as reflection, are not merely abstract concepts but are also applied in architectural designs to achieve balance and harmony (Silviana et al., 2024). Furthermore, this finding indicates that architectural design not only highlights aesthetic aspects but also incorporates geometric principles that can be explored in learning activities, enabling students to understand the concept of reflection more concretely through their surrounding environment.

Figure 6.
Composite Plane Figure on the Water Gate

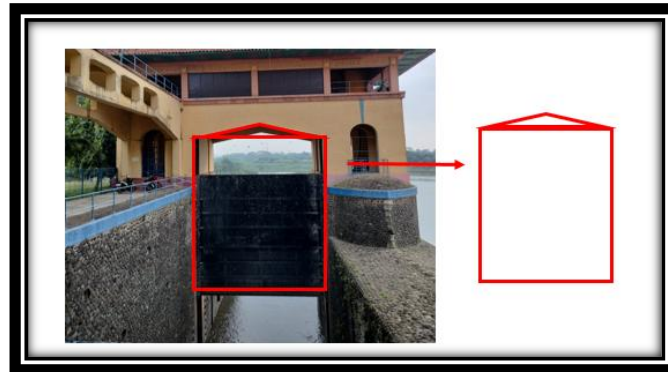
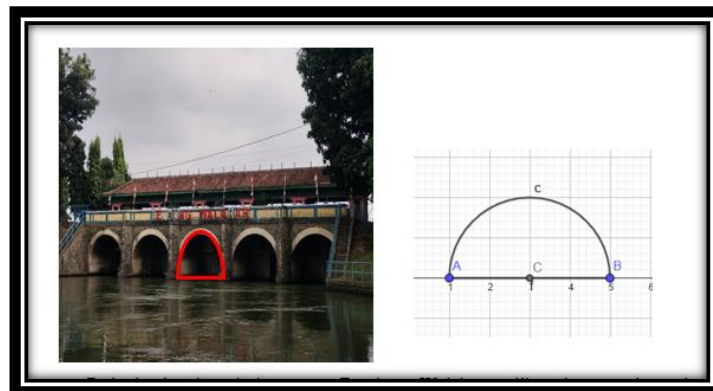


Figure 6 shows the upper part of the sixth water gate of the Walahar Dam, which displays a composite plane figure. This form consists of a rectangle that functions as the water gate and an isosceles triangle located at the top. The combination of these shapes not only provides structural strength and symmetry but is also designed as a ventilation channel suited to tropical climates, reflecting colonial architectural adaptation that prioritizes both functionality and aesthetics (Talib et al., 2025). This structure can serve as a concrete example for studying the concept of composite plane figures, as well as the application of triangles and rectangles in everyday contexts. In addition, formulas can be used to calculate the area and perimeter of the rectangular water gate.

$$\text{Area of a rectangle} = p \times l$$

$$\text{Perimeter of a rectangle} = 2(p + l)$$

Figure 7.
Semicircular Water Gates



In the lower section of the Walahar Dam building, a series of semicircular water gates can be observed. This section functions as a connecting channel that directs water flow from upstream to downstream. The semicircular arch shape is used in the water gates because, from a structural perspective, it is able to distribute water pressure more evenly to both sides of the wall, thereby providing greater strength compared to sharp-angled openings (Bu'ulolo et al., 2020). The use of curved forms is consistent with the characteristics of colonial architecture, which emphasizes large openings, good ventilation, and structural adaptation to tropical climates.

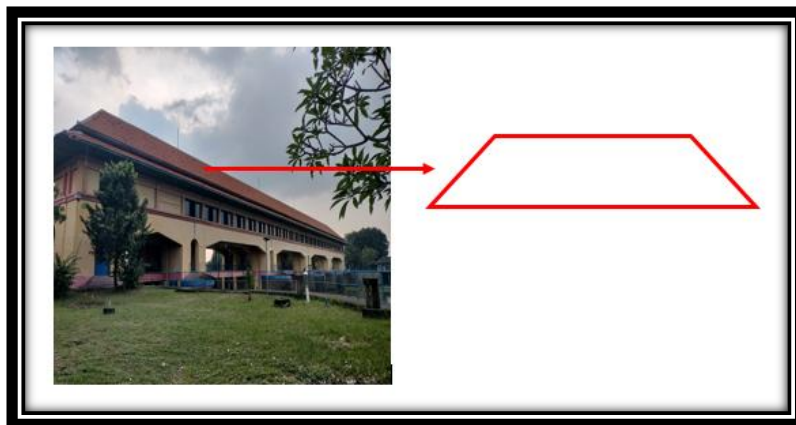
The semicircular arches of the Walahar Dam water gates serve as a concrete example of the application of circle geometry concepts in architecture. These arches can be examined through the elements of a circle, such as the center point, diameter, and arc. A circle is defined as a set of points on a plane that are equidistant from a fixed point known as the center (Faturrahman & Soro, 2021). Its properties include having a single curved side, possessing infinite rotational symmetry, with all points on its circumference equidistant from the center, and having no angles (Ni'mah & Marlina, 2021). Formulas can be applied to calculate the area and perimeter of the semicircular water gate arches.

$$\text{Area of a semicircle} = \frac{1}{2}\pi r^2$$

$$\text{Perimeter of a semicircle} = \frac{1}{2} \times 2\pi r$$

Figure 8.

Trapezoidal Roof of the Main Building



Based on Figure 8, it can be observed that the roof of the Walahar Dam building has a shape resembling an isosceles trapezoid. The upper base of the roof is shorter than the lower base, while the two sloping sides have relatively equal inclinations. The isosceles trapezoid form of the

Walahaar Dam roof has characteristics including one pair of parallel sides, two congruent angles, and adjacent angles whose measures sum to 180° (Zulfah et al., 2023). From a geometric perspective, the roof of the Walahaar Dam can therefore be used as a concrete example to relate the concepts of area and perimeter of a trapezoid to real objects in the surrounding environment.

$$\text{Area of a trapezoid} = \frac{1}{2}(a + b) \times t$$

$$\text{Perimeter of a trapezoid} = a + b + c + d$$

The trapezoidal roof form of the Walahaar Dam building represents an adaptation of colonial architecture to Indonesia's tropical climate. The differing roof slopes on each side allow rainwater to flow quickly, thereby reducing the risk of water splashing and pooling on the underlying structure. This design is consistent with the principles of colonial architecture, which modified European geometric forms to suit tropical conditions, particularly in utilitarian buildings that require resilience to extreme weather (Bu'ulolo et al., 2020). In addition to its technical function, the trapezoidal form provides a proportional and robust visual impression, reflecting a combination of colonial aesthetics and local environmental needs. This indicates that architectural elements are closely related to the application of geometric concepts, as evidenced in various traditional buildings that incorporate shapes such as triangles, trapezoids, and other geometric forms (Baharuddin et al., 2023). Furthermore, this finding demonstrates that mathematical principles are inherently embedded in cultural and environmental adaptations.

Overall, the results of the exploration indicate that the Walahaar Dam contains various representations of plane geometry concepts embedded in its architectural elements. These findings demonstrate that cultural and local architectural features can serve as contextual learning resources for mathematics education. By presenting tangible forms from the surrounding environment, students can more easily understand the relationship between abstract geometric concepts and their applications in everyday life. These findings are consistent with previous studies indicating that historical buildings contain various geometric concepts such as squares, rectangles, circles, and composite shapes (Zega & Narpila, 2024). Similar findings were also reported by previous studies (Silviana et al., 2024), which identified geometric concepts in historical buildings. However, this study provides a more comprehensive exploration by examining a wider range of geometric forms within a single structure.

These findings reinforce the role of ethnomathematics as a bridge between cultural heritage and mathematical understanding, as proposed by Ubiratan D'Ambrosio (1985). Furthermore, to provide a clearer and more structured overview of these findings, a summary of the relationship

between the identified geometric forms, the architectural functions of the structure, and their relevance to learning is presented in the following table.

Table 1.
Geometric Representations at the Walahar Dam

Dam Component	Geometric Shape	Geometric Concept	Architectural Function	Learning Implications
Entrance roof	Isosceles triangle	Side lengths, angles, symmetry, area, and perimeter of a triangle	Steep roof to accelerate rainwater flow; stable form to support the structure	Students can directly observe the properties of triangles and calculate area and perimeter using real objects
Ornamental decoration	Tessellation (repetitive square/rectangular patterns)	Repetitive patterns, symmetry, tessellation	Provides aesthetic value; reflects Chinese cultural motifs	Students can analyze tessellation patterns and symmetry in local cultural elements
Dam corridor	Combination of rectangle and semicircle	Composite shapes formed by combining rectangles and semicircles	Creates a functional passage that facilitates movement and connects structural sections efficiently	Student can analyze composite shapes and understand how geometric combinations are applied in real architectural designs
Windows	Rectangle and semicircle	Reflection symmetry and composite plane figures	Ventilation and natural lighting; strengthening colonial architectural identity	Students can observe symmetry and relate composite plane figures to real objects
Lower water gates	Semicircle	Radius, diameter, circumference, and arc	Withstands and distributes water pressure evenly	Students can relate circle concepts to the structural function of water gates
Upper water gate	Rectangle and triangle	Composite plane figures, area, and perimeter	Structural reinforcement and ventilation channel; colonial architectural adaptation	Students can calculate the area of composite figures and understand the functional combination of shapes

Dam Component	Geometric Shape	Geometric Concept	Architectural Function	Learning Implications
Main building roof	Isosceles trapezoid	Parallel sides, angles, area, and perimeter of a trapezoid	Adaptation to tropical climate; a more efficient rainwater runoff	Students can understand trapezoids as real-world shapes and relate their properties to architectural functions

4. Conclusion

The findings of this study highlight that the Walahar Dam contains diverse and dominant plane geometry concepts embedded in its architectural structures, such as triangles, rectangles, semicircles, trapezoids, and tessellations. These geometric elements not only serve structural and aesthetic functions but also reflect cultural values, making them meaningful learning resources. The study implies that integrating ethnomathematical contexts like the Walahar Dam into mathematics learning can enhance students' understanding by connecting abstract concepts with real-life situations. Future research is recommended to develop learning media or instructional designs based on these findings to support contextual mathematics education.

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